TITLE OF THE INVENTION

COMPATIBLE OPTICAL PICKUP USING LIGHT SOURCES FOLLOWING A COMMON OPTICAL PATH

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Korean Application No. 2000-42257, filed July 22, 2000, in the Korean Industrial Property Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to optical pickups compatible with recording media having different formats, and more particularly, to a compact optical pickup compatible with recording media with different formats, which uses a single light device module having two light beam sources with different light wavelengths.

Description of the Related Art

[0003] In recent years, there has been a need for an optical pickup capable of recording information on and/or reproducing information from a digital versatile disc-read only memory (DVD-ROM) at high densities that is compatible with the compact disc (CD) family of media. The CD family of media includes the CD, the recordable CD (CD-R), the CD rewritable (CD-RW), the CD interactive (CD-I), and the CD plus graphics (CD+G) compatible media.

[0004] The standard thickness of the CD family media is 1.2 mm, whereas the thickness of DVDs has been standardized to 0.6 mm, which takes in consideration of the allowable error in the tilt angle of an optical disc and the numerical aperture (NA) of an objective lens. Accordingly, when recording information on or reproducing information from a CD using an

optical pickup designed for DVDs, spherical aberrations occur due to a difference in the thicknesses therebetween. Such spherical aberration cannot provide a light intensity sufficient for recording an information (radio frequency) signal or may deteriorate a reproduction signal from the CD. Also, DVDs and CD families of media utilize different wavelengths of light for reproduction. Specifically, CDs use light having a wavelength of about 780nm, whereas DVDs use light having a wavelength of about 650nm. Thus, in order to be compatible with CDs, an optical pickup needs to use a light beam source capable of emitting different wavelengths of light, and capable of focusing optical spots at different focal positions.

[0005] Referring to FIG. 1, a conventional compatible optical pickup comprises a first light beam source 21 to emit a light having a wavelength of about 650nm, and a second light beam source 31 to emit a light having a wavelength of about 780nm. The first light beam source 21 is appropriate for a relatively thin optical disc 10a, such as a DVD, and the second light beam source 31 is appropriate for a relatively thick optical disc 10b, such as a CD. The thin optical disc 10a and the thick optical disc 10b are generically referred to as an optical disc 10.

[0006] Light emitted from the first light beam source 21 is collimated by a first collimator lens 23 to be parallel and incident on a first polarization beam splitter (PBS) 25, and then reflected by the first PBS 25 toward the thin optical disc 10a. After being reflected by the thin optical disc 10a, the reflected light is transmitted through the first PBS 25 and is received by a first photodetector 27. Here, an interference filter 41 that changes the paths of light emitted from the first and second light beam sources 21 and 31, a quarter-wave plate 43, a variable diaphragm 45, and an objective lens 47 to condense light incident are disposed on an optical path between the first PBS 25 and the thin optical disc 10a.

[0007] Light emitted from the second light beam source 31 is collimated by a second collimator lens 33 to be parallel and incident on a second PBS 35, transmitted through a condenser lens 37, and then incident on the interference filter 41. The light is reflected by the interference filter 41 and sequentially passes through the quarter-wave plate 43, the variable diaphragm 45, and the objective lens 47 to form an optical spot on the thick optical disc 10b.

[0008] Light reflected by the thick optical disc 10b is incident on the interference filter 41 through the objective lens 47, the variable diaphragm 45 and the quarter-wave plate 43, and

then reflected by the interference filter 41 towards the second PBS 35. The reflected light is reflected by the second PBS 35 and received by a second photodetector 39.

[0009] The interference filter 41, which is an optical element that transmits or reflects incident light depending on the wavelength of incident light, transmits the light originating from the first light beam source 21, and reflects the light originating from the second light beam source 31. The variable diaphragm 45 has a variable aperture, and defines the size of the light spot incident on the objective lens 47 such that the light beam enters the region of the objective lens 47 with an NA less than 0.45 or 0.47. The quarter-wave plate 43 is an optical element for changing the polarization of incident light. As each of the light beams from the first and second light beam sources 21 and 31 passes the quarter-wave plate 43 two times, the polarization of the incident beams changes, and then the light beams head toward the first PBS 25 and the second PBS 353, respectively. The objective lens 47 allows light from the first and second light beam sources 21 and 31 to be focused as a light spot on the corresponding recording surfaces of the thin optical disc 10a and the thick optical disc 10b.

[0010] Although the conventional optical pickup having the configuration described above is compatible with a CD-R using two light beam sources, the use of the variable diaphragm, which is manufactured through sophisticated and expensive processes, makes assembling of such an optical pickup complicated and increases the manufacturing cost. In addition, the first and second light beam sources are separately constructed to further complicate the configuration and optical arrangement of the optical pickup.

SUMMARY OF THE INVENTION

[0011] It is an object of the present invention to provide a compact optical pickup compatible with recording media having different formats, in which first and second light beam sources with different wavelengths of light are installed in a single light device module, and the optical paths of light beams from the first and second light beam sources are adjusted using a hologram light coupler.

[0012] Additional objects and advantages of the invention will be set forth in part in the description which follows and, in part, will be obvious from the description, or may be learned by practice of the invention.

[0013] To achieve the above and other objects of the present invention, an optical pickup includes a light device module having a first light beam source and a second light beam source to selectively emit corresponding first and second light beams having different wavelengths, a hologram light coupler to separately guide the first and second light beams along the same optical path such that the first and second light beams go toward a corresponding first and second recording media, an optical path changing unit to alter the optical path of an incident light beam, and an objective lens disposed on an optical path between the optical path changing unit and the corresponding first and second recording media to focus the first and second light beams on the corresponding first and second recording media, and a photodetector to receive the first and second light beams incident from the optical path changing unit after having been reflected from the corresponding first and second recording media, and to detect an information signal and error signals from the received light beams.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The above and other objects and advantages of the present invention will become apparent and more readily appreciated by describing in detail preferred embodiments thereof with reference to the accompanying drawings in which:

FIG. 1 is a schematic view showing the optical arrangement of a conventional compatible optical pickup;

FIG. 2 is a schematic view showing the optical arrangement of an optical pickup compatible with recording media having different formats according to an embodiment of the present invention;

FIG. 3 is a sectional view showing the pattern of a hologram light coupler used in the optical pickup according to an embodiment of the present invention;

FIG. 4 is a graph showing variations of transmittance with respect to the pattern depth of the hologram light coupler of FIG. 3;

FIG. 5 illustrates the diffraction efficiency of the hologram light coupler of FIG. 3;

FIG. 6 is a sectional view showing the pattern of another hologram light coupler used in the optical pickup according to another embodiment of the present invention;

FIG. 7 is a graph showing variations of transmittance with respect to the pattern depth of the hologram light coupler of FIG. 6;

FIG. 8 is a sectional view showing the pattern of yet another hologram light coupler adopted in the optical pickup according to yet another embodiment of the present invention;

FIG. 9 is a graph showing variations of transmittance with respect to the pattern depth of the hologram light coupler of FIG. 8;

FIG. 10 is a sectional view showing the pattern of still another hologram light coupler adopted in the optical pickup according to still another embodiment of the present invention;

FIG. 11 is a graph showing variations of transmittance with respect to the pattern depth of the hologram light coupler of FIG. 10;

FIG. 12 is a schematic front view of an objective lens used in the compatible optical pickup according to an embodiment of the present invention; and

FIGS. 13A and 13B are schematic views showing the objective lens focusing light according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0015] Reference will now be made in detail to the present preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to the like elements throughout. The embodiments are described below in order to explain the present invention by referring to the figures.

[0016] FIG. 2 shows an embodiment of an optical pickup compatible with recording media having different formats according to the present invention. The optical pickup includes a light device module 50, which includes first and second light beam sources 55 and 57 to emit a first light beam I and a second light beam II having different respective wavelengths, a hologram light coupler 61 by which the first and second light beams I and II are guided to travel along the same optical path, an optical path changing unit 63 to selectively alter the optical path of incident light, a collimator lens 66 to collimate incident light, an objective lens 67 to focus incident light on an optical recording medium 80, and a photodetector 71 to receive light passed through the objective lens 67, the collimating lens 66, and the optical path changing unit 63 after having been reflected from the recording medium 80.

[0017] In particular, the light device module 50 includes a substrate 51, a mount 53 on the substrate 51, and the first and second light beam sources 55 and 57 attached to corresponding sides of the mount 53. The first and second light beam sources 55 and 57 are edge emitting lasers that emit light beams at different and diverging angles. The first light beam I from the first light beam source 55 has a wavelength of about 650 nm, and is appropriate for a relatively thin optical disc 80a, such as a DVD. The second light beam II from the second light beam source 57 has a wavelength of about 780 nm, and is appropriate for a relatively thick optical disc 80b, such as CDs. The positional tolerance between the first and second light beam sources 55 and 57 can be controlled by adjusting the location of the hologram light coupler 61 on the optical path between the light device module 50 and the objective lens 67.

[0018] The hologram light coupler 61 guides the first and second light beams I and II along the same optical path and directs the first and second light beams I and II toward the optical recording medium 80. The hologram light coupler 61 has a hologram pattern 61a shown in FIG. 3 at one surface thereof to diffract and transmit incident light. The hologram light coupler 61 directly transmits the first light beam I entering along a light path that is perpendicular to the light receiving surface of the hologram light coupler 61, and diffracts and transmits most of the second light beam II along a light path that is incident at an angle such that transmitted portions of the second light beam II are parallel to the transmitted first light beam I. Transmittance of the hologram light coupler 61 is determined by the depth of the hologram pattern 61a, the pitch of the hologram pattern 61a, and the configuration of the hologram pattern 61a. As shown, the hologram pattern 61a of the hologram light coupler 61 has a stepped pattern including at least two steps.

[0019] FIG. 3 illustrates an example of the hologram pattern 61a having five steps, and FIG. 4 illustrates variations of transmittance of the first and second light beams I and II with respect to the variations of maximum pattern depth D_p of the hologram pattern 61a of FIG. 3. Referring to FIG. 4, at a maximum pattern depth D_p of about 6,400 nm, the transmittance of the hologram light coupler 61 is about 1.0 for the principle zeroth order maximum of the first light beam I having a 650nm wavelength. The second light beam II is diffracted and transmitted into zeroth order and 1st order diffracted beams. As shown in FIG. 5, the transmittance of the hologram light coupler 61 is about 8% for the zeroth order diffracted beam, almost 0% for the $+1^{st}$ order diffracted beam, and about 75% for the -1^{st} order diffracted beam with respect to the amount of

the incident light. The -1^{st} order diffracted beam serves as the effective beam for the second light beam II, and travels parallel to the zeroth order diffracted beam from the first light beam I.

[0020] While the -1^{st} order light of the second light beam II is shown in FIG. 5 as being slightly non-parallel to the 0^{th} order light of the first light beam I, this non-parallel depiction is for the purposes of clarity.

[0021] As previously mentioned, the hologram light coupler 61 is appropriately located on the optical path such that the first and second light beams I and II from the first and second light beam sources 55 and 57, which are installed in the light device module 50 but at different angles with respect to the optical axis, are guided along the same optical path and go toward the optical recording medium 80.

[0022] Although the hologram light coupler 61 of FIG. 3 has a 5-step hologram pattern, the hologram pattern of the hologram light coupler 61 can be varied as shown in FIGS. 6, 8 and 10. FIG. 6 illustrates a 4-step hologram pattern 61a for the hologram light coupler 61, and FIG. 7 illustrates variations of transmittance for the first and second light beams I and II with respect to the maximum pattern depth D_p. In designing the hologram pattern 61a shown in FIG. 6, the phase of the light beam is also considered. For the 4-step hologram pattern of FIG. 6, the pitch TP1 at the maximum pattern depth D_p is larger than the pitches TP2, TP3 and TP4 for the other steps.

[0023] Referring to FIG. 7, at a maximum pattern depth D_p of about 4,900 nm, the transmittance of the hologram light coupler 61 is about 1.0 for the zeroth order maximum of the first light beam I having a 650nm wavelength. The second light beam II is diffracted and transmitted into zeroth order and -1^{st} order diffracted beams. The transmittance of the hologram light coupler 61 is about 10% for the zeroth order diffracted beam, almost 0% for the $+1^{st}$ order diffracted beam, and about 65% for the -1^{st} order diffracted beam with respect to the amount of the incident light. The -1^{st} order diffracted beam serves as the effective beam for the second light beam II, and travels parallel to the zeroth order diffracted beam from the first light beam I.

[0024] FIG. 8 illustrates another 4-step hologram pattern 61a for the hologram light coupler 61 in which no phase of light beam is considered, and FIG. 9 illustrates variations of transmittance for the first and second light beams I and II with respect to the maximum pattern depth D_p. For the 4-step hologram pattern of FIG. 8, the pitch TP1 at the maximum pattern depth D_p is equal to the pitches TP2, TP3 and TP4 for each of the other steps.

[0025] Referring to FIG. 9, at maximum pattern depth D_p of about 4,900 nm, the transmittance of the hologram light coupler 61 is about 1.0 for the zeroth order maximum of the first light beam I having a 650nm wavelength. The transmittance of the hologram light coupler 61 is almost 0% for both the zeroth order diffracted beam and $+1^{st}$ order diffracted beam from the second light beam II, and about 86% for the -1^{st} order diffracted beam with respect to the amount of the incident light. The -1^{st} order diffracted beam serves as the effective beam for the second light beam II, and travels parallel to the zeroth order diffracted beam from the first light beam I. While not shown, it is understood that other non-zeroth order lights may serve as the effective beam for the second light beam II.

[0026] FIG. 10 illustrates a 2-step hologram pattern 61a for the hologram light coupler 61, in which no phase of light beam is considered, and FIG. 11 illustrates variations of transmittance for the first and second light beams I and II with respect to the maximum pattern depth D_p. For the 2-step hologram pattern of FIG. 10, the pitch TP1 at the maximum pattern depth D_p is equal to the pitch TP2 of the other step of the hologram pattern.

[0027] Referring to FIG. 11, at a maximum pattern depth D_p of about 4,900 nm, the transmittance of the hologram light coupler 61 is about 1.0 for the zeroth order maximum of the first light beam I of wavelength 650nm. The transmittance of the hologram light coupler 61 is almost 0% for both the zeroth order diffracted beam and $+1^{st}$ order diffracted beam from the second light beam II, and about 68% for the 1st order diffracted beam with respect to the amount of the incident light. The -1^{st} order diffracted beam serves as the effective beam for the second light beam II, and travels parallel to the zeroth order diffracted beam from the first light beam I.

[0028] As can be inferred from the embodiments of the hologram pattern 61a for the hologram light coupler 61 illustrated above, the maximum pattern depth D_p of the hologram light

coupler 61 can be varied according to the stepped configuration. It is preferable that the maximum hologram depth D_p of the hologram light coupler 61 satisfies the expression: 4,000 nm $\leq D_p \leq$ 7,000 nm.

[0029] As previously mentioned, the zeroth order diffracted beam is utilized as the effective beam for the first light beam I, and the -1^{st} order diffracted beam is utilized as the effective beam for the second light beam II. For this reason, the first and second light beams I and II emerging from the different light beam sources 55 and 57 separated from each other can travel on the same optical path. The first and second light beams I and II pass through the hologram light coupler 61 to diverge at different angles, so that the first light beam I is focused on the thin optical disc 80a and the second light beam II is focused on the thick optical disc 80b.

[0030] While not shown, it is understood that the first light beam I and the second light beam II could both be diffracted by the hologram light coupler 61. For instance, it would be possible for both the first and second light beams I and II be incident at non-perpendicular angles such that the -1^{st} order light of the first light beam is parallel to the -1^{st} order light of the second light beam.

[0031] Turning to FIG. 2, the optical path changing unit 63 comprises a polarization beam splitter (PBS) 63 to selectively alter the optical path of incident light beams by transmitting or reflecting incident light beams according to their polarization, and a quarter-wave plate 65, which is disposed on the optical path between the PBS 63 and the objective lens 67, to change a polarization of the incident light beams. The light beams emitted from the light device module 50 pass through the PBS 63 and go toward the optical recording medium 80.

[0032] As a light beam heads toward the optical recording medium 80, and the light beam reflected from the optical recording medium 80 passes through the quarter-wave plate 65, the polarization of incident light beam changes. After the light beam reflected by the optical recording medium 80 is incident on the PBS 63, the incident light beam is reflected by the PBS 63 such that it goes toward the photodetector 71.

[0033] The objective lens 67 focuses the incident first or second light beams I and II on the corresponding thin optical disc 80a or the thick optical disc 80b. To achieve this, the objective

lens 67 has a light receiving surface to receive light emitted from the light device module 50, and a light emitting surface disposed opposite the optical recording medium 80. It is preferable that at least one of the light receiving and transmitting surfaces is divided into concentric sections by at least one annular region. As shown in FIG. 2, each of the sections has a different aspheric curvature such that light beams passed through the sections can be focused at different positions.

[0034] In particular, referring to FIGS. 12 and 13, the objective lens 67 includes a near-axis region 67a, an annular lens region 67b, and a far-axis region 67c. The annular lens region 67b located between the near-axis region 67a and the far-axis region 67c is curved, and may be formed as a circular or elliptical ring. The annular lens region 67b has an aspherical surface. It is preferable that the annular lens region 67b is optimized for the thick optical disc 80b.

[0035] When the thin optical disc 80a is used as the optical recording medium 80, the light beam I emitted from the first light beam source 55 is focused as a light spot on the information recording surface of the thin optical disc 80a through the far-axis region 67c. In contrast, the portion of the light beam I emerging from the annular lens region 67b is scattered.

[0036] On the other hand, when the thick optical disc 80b is used as the optical recording medium 80, the second light beam II emitted from the second light beam source 55 is focused as a light spot on the information recording surface of the thick optical disc 80b through both the annular lens region 67b and the near-axis region 67a.

[0037] While not shown, it is understood that there are other mechanisms by which this focusing can be accomplished. For instance, it is understood that it would be possible to perform the selective focusing by adjusting the focal length/working distance between optical discs 80a and 80b and the objective lens 67.

[0038] As shown in FIG. 2, the optical pickup further includes the collimating lens 66 on the optical path between the objective lens 67 and the quarter-wave plate 65, to collimate incident light. However, it is understood that a collimating leans 66 is not required in all instances.

[0039] The photodetector 71 receives the first light beam I or second light beam II light incident from the optical path changing unit 63 after having been reflected from the optical recording medium 80, and detects an information signal and error signals from the incident light. A sensor lens 69 to cause an astigmatism to the incident light is disposed on the optical path between the PBS 63 and the photodetector 71. However, it is understood that the sensor lens 69 and/or the PBS 63 need not be used in all instances, such as when the photodetector 71 is mounted on the mount 53.

[0040] Further, it is understood that the locations of the photodetector 71 and the light module 50 might be exchanged such that the optical path changing unit 63 reflects the first and second light beams I and II from the light module, and transmits the first and second light beams I and II reflected from the optical disc 80.

[0041] As previously mentioned, the optical pickup according to the present invention, which is compatible with recording media having different formats, uses a single light device module in which first and second light beam sources having different wavelengths of light are installed, and uses a hologram light coupler such that light beams from the first and second light beam sources, which are separated from each other, are guided along the same optical path. In addition, the optical pickup according to the present invention detects an information signal and error signals with a single photodetector. Thus, the configuration of the optical pickup becomes compact and simplified.

[0042] While this invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the claims and their equivalents.